Quantification of the relative efficiency of factory surveillance in the disclosure of tuberculosis lesions in attested Irish cattle


In Ireland, factory surveillance of cattle for gross lesions is an important supplementary method for detecting herds infected with bovine tuberculosis (TB), and in recent years between 27 and 46 per cent of all new herd breakdowns in any year have been detected by this method. The aim of this study was to determine the relative efficiency of factories in detecting lesions among attested cattle slaughtered during 2003 and 2004. National databases were available on animal slaughter, programmes of tuberculin testing for bovine TB and laboratory confirmation of suspected lesions. Factories were ranked according to their submission risk (number of animals submitted with lesions/number of attested animals killed) and confirmation risk (number of animals with laboratory-confirmed lesions/number of animals submitted with lesions), and adjusted for the risk profile of the attested cattle using factors such as their age and sex.

There are complexities when quantifying the efficiency of factory surveillance because of the potential for major differences, in terms of bovine TB status, in the population of cattle being slaughtered at each factory. First, factors affecting the bovine TB status of cattle are likely to affect the efficiency of surveillance include physical factors, such as line speed and light intensity, and human factors, such as the quality of inspection, as influenced by the competence of the inspector, and several preliminary studies have been made, some based on univariable analyses (de Kantor and others 1997, Corner and others 1999, Koebe and others 2000, Lenehan and others 2000) and one on a multivariable analysis (Martin and others 2003). The multivariable approach is preferable because it ensures that measures of efficiency are adjusted for the likely bovine TB status of the slaughtered cattle at each factory.

The aim of this study was to determine the relative efficiency of factories in disclosing lesions in attested cattle, on the basis of the submission of lesions and their confirmation as bovine TB. The analyses have attempted to control for a broad range of potential confounding factors, including the geographical risk of infection, the bovine TB history of the farms of origin, the animals’ characteristics (age, sex and whether they were homebred) and the season of slaughter.

The studies are based on data relating to lesions submitted and confirmed as bovine TB during 2003 and 2004.


databases

The data were obtained from the Centre for Veterinary Epidemiology and Risk Analysis at University College Dublin, Ireland. Three primary databases were used, as follows.
Animal movement Data were available on 3,678,914 cattle slaughtered in 2003 or 2004, including their identification number, birth date, slaughter date and sex, and the herd’s identification number.

Tuberculin test results Results were available for all of the tuberculin tests conducted in Ireland after January 1990. All herds are tested at least once annually, but herds with confirmed or suspected bovine TB are tested more frequently. The information derived from this database included each herd’s identification number, its locality in terms of its District Electoral Division (DED), the testing date, the number of reactors and the total number of animals tested. These data were used to calculate the level of bovine TB, at animal level, in the herds where each herd was located, on the basis of the number of positive single intradermal comparative tuberculin tests (SICTTs) divided by the total number of SICTTs conducted between 1997 and 2004.

Laboratory results The laboratory database contained 7398 records of examinations conducted on lymph nodes and other materials submitted from animals from attested herds, that is, animals sent to slaughter with an animal identity card, other materials submitted from animals from attested herds, and no evidence of bovine TB before the animal was slaughtered.

Analyses The data were used to calculate the number of attested animals that were slaughtered, the number of slaughtered animals from which at least one lesion was submitted for further examination, and the number of slaughtered animals from which at least one lesion was confirmed as being positive for bovine TB.

Submission risk A multivariable logistic regression model was developed to calculate the risk of lesion submission for each factory, while adjusting for the other potential confounding factors. Using animal as the unit of interest, the following model was used:

\[
\text{Logit} \{P(Y=1|F+x)\} = \mu + F + x_1 \ldots x_6
\]

where: \(P(Y=1|F+x)\) is the probability that a lesion was submitted for laboratory confirmation from an attested animal at slaughter by factory \(F\), while adjusting for a set of confounders \((x)\); \(\mu\) is the overall mean; \(F\) is the factory (42 classes); \(x_1\) is the sex (two classes: male and female); \(x_2\) is the animal’s age (nine classes: 0 to one year old, 1 One to two years, 2 Two to three years, 3 Three to four years, 4 Four years or longer); \(x_3\) is the DED risk (four classes: very low, low, medium, high); \(x_4\) is whether the animal was homebred or purchased; \(x_5\) is the slaughter season (four classes, each being one quarter of a year); \(x_6\) is the length of the clear period of the herd of origin (five classes: 0 Less than one year, 1 One to two years, 2 Two to three years, 3 Three to four years, 4 Four years or longer); \(x_7\) is the slaughter season (four classes, each being one quarter of a year); \(x_8\) is the sex (two classes: male and female); \(x_9\) is the animal’s age (nine classes: 0 to one year old, 1 One to two years old . . . 8 Eight years and older); \(x_{10}\) is the DED risk (four classes: very low, low, medium, high); \(x_{11}\) is whether the animal was homebred or purchased.

The DED risk was based on the quartiles (25 per cent, 50 per cent and 75 per cent) of the reactors per 1000 animals tested. These quartiles were 1-6, 2-5 and 4-8. Ireland is...
divided into 3440 DEDs, and animals from 2845 of these were slaughtered during 2003 and 2004.

**Confirmation risk** A comparable model was used to analyse the effect of factory on the risk of bovine TB being confirmed in the lesions submitted, using animal as the unit of interest. Samples from which *M bovis* was not isolated and no alternative diagnosis was made were considered to be negative, and the sensitivity of the laboratory tests was assumed to be constant. All analyses were made using SAS v8.2 (SAS).

Adjusted submission and confirmation risks were derived from the output of the logistic regression, and the factories were ranked accordingly. The adjusted and unadjusted risks were compared to determine the effect of this adjustment on the estimates of risk and on the ranking of the factories.

### RESULTS

**Descriptive data** Data were available on 3,678,914 cattle, including 3,491,468 (94.9 per cent) slaughtered at one of the 42 export-licensed factories and 3,440,757 from attested herds. In the final multivariable models, 2,374,987 attested animals (64.6 per cent of all the animals slaughtered, and 69.0 per cent of the animals from attested herds) were included, from 84,510 herds in 2845 DEDs. Data on approximately one million potentially eligible animals were not included, either because data were
missing about their birth date or sex (mainly animals born before the animal identification and registration system was fully operational), or because they had not been present in the source herd at the time of the last herd test, or because the attested status of the herd had been misclassified (although these animals were accompanied by an identity card, suggesting an attested herd status, they had been tested either as an inconclusive skin reactor or derived from a herd under bovine TB restriction).

Lesions from 7398 animals from attested herds were submitted for laboratory confirmation. Complete data suitable for the multivariable analyses were available for 4973 of these animals. Lesions from 3088 (62·1 per cent) animals from 2506 herds (on average, 1·23 lesions per herd) were confirmed as being positive for bovine TB; 1451 (29·2 per cent) tested negative and 434 (8·7 per cent) were classified as inconclusive.

The adjusted factory submission risk ranged from 0 to 65 per 10,000, with an average of 22 and a median of 22 (Table 2, Fig 1). After excluding the eight factories that submitted suspected lesions from fewer than 10 animals, the submission risk ranged from seven to 65 per 10,000. The correlation between the adjusted and unadjusted submission risks (based on the data for animals with complete records) was
confirmed as bovine tuberculosis

FIG 2: Numbers of factories with different risks of having suspected lesions being confirmed as bovine tuberculosis

The overall confirmation risk was 63·5 per cent. Among the 36 factories that submitted at least 10 animals, the confirmation risk varied from 33·7 to 86·1 per cent (Table 3, Fig 2). Neither the adjustment for confounding factors nor the inclusion of records with incomplete information about these factors affected the ranking of the factories. There were very high correlations between the unadjusted and adjusted confirmation risks for the animals with complete information about confounding factors (0·99) and for those without (0·98).

The association between the submission and confirmation risks at each factory was significant when the crude risks were compared (r=−0·36, P<0·05), but not when the adjusted risks were compared (r=−0·26, P=0·12).

DISCUSSION

The aim of this study was to compare the efficiency of export-licensed factories in detecting lesions of bovine TB among attested cattle, by comparing their rates of submission of lesions and their rates of confirmation of the disease. Differences could be important, because between 27 and 43 per cent of new herd breakdowns in any one year between 1993 and 2001 were first detected through factory surveillance (O’Keeffe and White 1999; T. Clegg, personal communication). National databases of cattle slaughter, tuberculin testing and laboratory findings were used to make the comparisons.

There were substantial variations between the surveillance efficiency of the 42 factories, in terms of both the risk of submission and of confirmation. The observed factory submission risk ranged from 0 to 58 per 10,000 animals slaughtered (Table 2) with an average of 22 per 10,000, and there was a ninefold range in the submission risk after the factories that submitted fewer than 10 animals had been excluded. These results are in broad agreement with the results of Martin and others (2003), who found a sevenfold difference between factories after controlling for year, month and animal type. Similarly, the factory confirmation risk ranged from 33·7 to 86·1 per cent, with an average of 63 per cent. In broad terms, two explanations for these variations are possible: there may be considerable differences between the risk profiles of the cattle slaughtered at each of the factories, and the factories may vary substantially in their efficiency and/or accuracy of detecting lesions, affecting their submission and confirmation risk, respectively. A range of factors, including location and type of animal, are known to affect the infection risk of Irish cattle, and factories often slaughter cattle of a defined type and/or from a relatively well defined geographical area. Through multivariable modelling, a number of known animal- and farm-level confounding factors have been controlled for. However, the variations in the risk profile of the animals among the factories were substantially less than expected, given the close agreement between the crude and adjusted estimates of factory risk, and it can therefore be concluded that animal- and farm-related factors did not contribute significantly to the variations in factory-level submission and confirmation risks observed. By exclusion, therefore, factory-level factors would have accounted for much of the variation in factory efficiency. Collins (1997) suggested that variations in factory surveillance efficiency may be due to factory-related circumstances, for example, line speed and light intensity, and/or to factors related to the veterinary inspector, for example, their experience, interest, motivation and workload. These possible factors are being considered in both industry and government, and further research may be warranted. It will be important to continue to monitor the submission and confirmation risks in Irish factories to assess the efficacy of any changes that are introduced.

A confirmation risk of 100 per cent is neither achievable nor desirable. Granulomas due to bovine TB cannot be distinguished from non-tuberculous granulomas, such as those due to infection with Actinobacillus lignieresii, on the basis of visual inspection, incision and palpation alone, and further laboratory examination is therefore needed. Inspectors should be encouraged to maximise sensitivity, rather than specificity, to maximise the number of bovine TB lesions detected, and thus the efficiency of factory surveillance in identifying bovine TB-infected herds. In the Australian programme, meat inspectors are encouraged to submit all granulomas, rather than just those that appear to be bovine TB granulomas, to the laboratory for examination by histopathology and/or culture (Radunz 2006). In Ireland, there is substantial variation between the confirmation risks of different factories, indicating that the practices applied in submitting lesions are not uniform. As would be expected, there was a small negative correlation between the submission risk and the confirmation risk; as the number of submissions increased, the percentage of the lesions that were confirmed as bovine TB decreased.

The exclusion of animals with incomplete data reduced the average crude risk of submission from 0·22 per cent to 0·19 per cent (Table 2). Animals were excluded mainly because of missing birth dates; most of them were probably older animals, because the animal identification system was not fully operational before 1996. The inspection of older animals had a higher probability of disclosing lesions of bovine TB (Table 1), probably because they had been at risk of exposure for longer and had a greater chance of having completed the incubation period; hence the lower crude submission risks when animals with incomplete information were excluded. The exclusion of
data on these animals did not change the ranking of the factors with respect to their crude submission risk.

The submission and confirmation risks both varied considerably, as a result of a range of factors including the animal’s age, sex, the season of slaughter, and whether it was homebred, and the location and past bovine TB history of its farm of origin. These findings are consistent with the results on the influence of location by O’Keeffe and others (2002), on past bovine TB history by Olea-Popelka (2002) and Olea-Popelka and others (2003), and on the age of the animals by Martin and others (2002), all in the Irish setting. The more reactors found in the DED from which the animal came, the higher were the odds of a suspect lesion being submitted (DED risk class). Animals from herds in which a reactor had been detected in the previous two years also had higher odds of a suspect lesion being submitted. The seasonal pattern in laboratory submissions was similar to the pattern found by Martin and others (2003), which may be related to the seasonal exposure between badgers and cattle, as suggested by Martin and others (2002). During winter, when food resources are less plentiful, it is possible that badgers may more often gain access to cattle housing and forage in cattle troughs, with the potential to increase exposure of cattle to infected badgers (Garnett and others 2002).

Field surveillance is the primary method of detecting bovine TB infections in Irish herds. All Irish cattle are tested by the SICTT at least once a year, and the majority of new herd breakdowns are detected by this annual procedure. As part of the current programme, factory surveillance makes it possible to detect infection during the period between annual tests, thereby reducing the magnitude of the herd problem and the risk of the disease spreading between herds. No further reactors are found at subsequent SICTTs in approximately 80 per cent of herd breakdowns first detected during factory surveillance (F. J. Olea-Popelka, P. W. White, E. Costello, G. McGrath, J. D. Collins, J. O’Keeffe, D. F. Keltan, O. Berke, S. J. More, S. W. Martin, unpublished observations). In many cases it is suspected that the infected animals may have been infected for a long time but were not reactive to the annual SICTT. They could presumably have become infectious, with the potential to spread bovine TB within the herd and between herds at some time in the future. Furthermore, from the perspective of food safety, factory surveillance prevents the carcasses of animals with generalised bovine TB from entering the food chain. Carcasses of animals with localised or suspected lesions can enter the food chain without posing any known threat to food safety (European Food Safety Authority 2003).

Improved factory surveillance would contribute to national efforts to control bovine TB. The identification of infected herds before the scheduled annual or other tuberculin test would help to minimise the size of major breakdowns in an index herd and the spread of infection from an index herd to contiguous herds. During 2003 and 2004, there were substantial differences between the surveillance efficiencies of Irish factories, as measured by their risks of submitting lesions and having them confirmed. These differences were unlikely to have been attributable to differences in the risk profile of the cattle slaughtered at each factory. They are more likely to have been due to inherent differences between the factories. Although factory surveillance is not the primary method for detecting bovine TB infections in Irish herds, it plays an important role in the early detection of infected herds and in the detection of animals that are not reactive to the tuberculin test. Improvements in the efficiency of factory surveillance would improve bovine TB disease control and help to ensure that measures to safeguard food safety are enforced.

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Veterinary Record 2007 161: 679-684
doi: 10.1136/vr.161.20.679

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